in nowise detracts from their permanent value to the broad science of geology.

An example of work on a broad problem that concerns a number of states is afforded by the general and detailed study of the Atlantic and Gulf Coastal Plain which for five years has been prosecuted under the direction of T. W. Vaughan with the cooperation of several state and federal geologists. Similarly, the mapping of the San Juan region by Whitman Cross serves as a notable example of a general investigation of broad scientific interest, covering two decades. A third illustration is to be found in the geologic work of Messrs. Campbell and Alden in the new Glacier National Park. It is conceivable that the publications resulting from such geologic investigations will stand as large contributions to science, and when this literature has been illumined by the added glamor of the years, the Geological Survey of to-day may be cited as again "the center of the world for the advancement of the science of geology."

More than this, the application of geology to economic problems has a reflex effect upon the science. The association of the scientist with the engineer is beneficial to both. The geology that is applied to big problems, whether of engineering or of governmental policy, must be not only qualitatively true, but also quantitatively exact. So the entrance of the Geological Survey into the administration of the public lands has modified field methods and established standards of accuracy not before demanded. The result is that the geologist who works in terms of forty-acre tracts observes details that were overlooked by his predecessor who looked the country over by the square mile.

The recognition of the applicability of geologic data collected by government scientists to the administration of the public lands is in itself, I believe, a large contribution to the advancement of science. The field of science is broadened and the standing of science is dignified. The remark of the geologist whose experience had been gained largely in the east but who is now working in a western mining camp illustrates this: "It is a satisfaction to be looked upon as a worker and not have to make apologetic explanations as to what geology means."

Another illustration is afforded in the work of the Geological Survey in connection with the proposed forest reservations in the east. For years the geologists and hydrographers of the Survey had taken interest in the question of the relation of forest cover to stream flow and as opportunity afforded had made observations bearing on the question. The results, however, were at best only qualitative and to some extent confusing. The Weeks Act, however, specifically laid upon the Survey the burden of making an affirmative showing of the regulative effect of the forest upon stream flow, before land could be purchased, and then an investigation was planned with the purpose of obtaining conclusive results. That the Survey withstood popular clamor until its investigation was concluded and reported only on observed facts may of itself have been a possible aid in advancing science. As an intensive study, the hydrometric survey of selected areas in the White Mountains is believed to be without parallel in the world, and it has yielded quantitative results which, when thoroughly digested and compiled, will be published as an important contribution to science. This opportunity to apply science to an administrative problem came to the Geological Survey because its work was believed to be both practical and scientific; and I may add my opinion that whenever this bureau becomes exclusively "practical" or exclusively "scientific" it will cease to deserve either recognition or support. This idea has been best expressed by Brooks: "Applied geology can maintain its present high position of usefulness only by continuing the researches which advance the knowledge of basic principles."

GEO. OTIS SMITH

SCHOOL GRADES—TO WHAT TYPE OF DISTRIBUTION SHALL THEY CONFORM?

THOSE administrators who have given the subject of scholarship marks or school grades considerable attention, will appreciate President Wm. T. Foster's article, "The Scientific

Distribution of Grades at Reed College," which appeared in the June 7, 1912, issue of SCIENCE.

Without wishing to criticize the Reed College system which the writer considers amply adequate to bring about uniformity in grading at Reed College itself, there yet remains the question, is the Reed College system the one most likely to be adopted by other educational institutions? The extent to which the question of grading is at present agitated justifies the conclusion that there is a tendency toward the standardization of grades—not only within the walls of a given school, but among the schools themselves. As long as no absolute units for mental measurement exist, the one essential factor for standardized grades is that the *form* of the distribution of these grades be identical for the various institutions. If this is true, the question arises what form of distribution shall be adopted?

The form adopted by Reed College is a modification of the normal curve, *skewed* to take account of the "selected nature of college students." It is this question—the advisability of skewing the normal curve—which is to be considered in this paper.

From present indications, if the various educational institutions throughout the country were suddenly obliged to adopt a uniform type of distribution for their grades, it is probable that the normal type of distribution is the one which would be most readily accepted. As soon as deviations, either in one direction or the other, are suggested, each faculty would insist on skewing the curve in the direction which would best express, in the opinion of the faculty, the local conditions. If the different school faculties are encouraged to express in their grades the degree of selection which they believe to exist in their student body, the personal element will again become so strong as to eliminate the uniformity which a scientific system is supposed to introduce. In a faculty composed mainly of "home talent" there is a tendency to suppose that its particular students are a specially selected group with respect to intelligence, and under such conditions it may happen that a faculty will adopt a form of distribution in which *all* of the students are supposed to be above the general average instead of only three fourths, as is done in the Reed College curve.

Until a system of absolute mental units has been invented, it is futile to try to make grades represent absolute accomplishment. The best that can be done under the conditions is to let the grades express *relative* accomplishment. It should be clear that skewing the normal curve is an attempt to make grades represent absolute accomplishment in that the degree of deviation from the normal type of distribution is supposed to measure the degree of superiority or inferiority, above or below some hypothetical absolute accomplishment of the population at large. Since we do not know enough about the intellectual capacity of the population at large to gain general acceptance for such numerical values as we might choose to assign, perhaps it would be better, for the present, to be satisfied with measuring relative accomplishment. To justify the deviation from the normal curve shown by the Reed College system, it seems that the following two factors should permit of quantitative statement.

1. The *numerical degree* of the selection with respect to *scholarship*.

2. The difference in the *form* of the distribution of the selected group, from that of the unselected group.

With respect to (1) it is doubtful whether the data at our disposal are of such convincing validity as to justify our giving it numerical values, especially when we consider not only those students who fail to attend the university after finishing their high-school work, but also those who drop out during the first, second and third high-school years. Many students leave high school because their parents have not the means to enable them to continue; some students get dissatisfied with the school work and prevail upon their parents to let them go out and do "real work." It is not necessary here to indicate the many reasons for which children leave the high

school—reasons which have nothing to do with the intellectual ability of the student. The percentage of successful men and women who have never completed a high school course is still too large to warrant the conclusion that the elimination which takes place can be accurately expressed in terms of scholarship. That some selection with respect to scholarship takes place may very well be admitted but at present we are not in a position to isolate this from the numerous other factors which make college enrollment less than that of the high schools.

Further, to assume that 75 per cent. of its students are above the general average, as is done in the Reed College system, is a verdict which should come from some other source than Reed College. If it is found, for instance, that Reed College graduates invariably do better work than the graduate students from other schools, it would be possible to calculate the superiority of Reed College students. This is the only sense in which the term selection would have any significance. It is the product, not the raw material, which should characterize a school.

Reed College could also calculate the relative standing of the high schools from which it draws its students. This would be a comparatively simple task if all the high schools graded their students in strict compliance with the normal curve, but if the several schools adopted curves which deviated from the normal, each school deviating to the extent which most appealed to it, an attempt at fixing a definite value for a particular grade would be almost as hopeless a task as it is now.

If, however, all educational institutions awarded grades strictly in compliance with the normal curve, these grades would at least express the same *relative* scholarship. If then the graduate schools found that the students from one institution did better work than students having the same grade from other institutions, the graduate schools could easily calculate a selection coefficient which would express the degree of selection for the different schools. Of course, this can not be done at the present time, but the writer merely wishes to point out that the factor of selection can not be scientifically evaluated with the data now at our disposal. To encourage a faculty to express this ambiguity in its grades is only transferring the grading idiosyncrasies from the individual instructor to the faculty.

With respect to (2), it is questionable whether the selection of scholarship which exists is of such a nature as to change the *form* of the distribution in a measurable degree. It is of course to be understood that the average accomplishment of a poor class may be less than the average accomplishment of a better class, but it does not follow that the grades are distributed differently on either side of the respective class averages.

An elementary class in experimental psychology of about 150 students at the University of Missouri were graded for a whole semester according to the average accomplishment of the whole class. The Ebbinghaus conjectural method of examination was used so that the personal equation of the instructor might be eliminated as much as possible, and also to approach more closely to the absolute accomplishment of the students.[1] The correlation between the actual grades and those expected from a normal type of distribution was then calculated according to the following scheme.

Number of Examinations	Extent of Correlation with Normal
1	.730
2	.970
9	.996

We have here a gradual approach toward the normal type of distribution. If only a single examination is given the distribution may be decidedly skewed. This does not, however, show conclusively that the scholarship is not normally distributed. If the examination does not fairly test the scholarship of the

[1] A more detailed report of this investigation is to be found in *The Journal of Experimental Pedagogy and Training College Record* (Sheffield), Vol. 1, No. 4, June, 1912.

class, if it is too easy or too difficult, a skewed distribution may result even if the scholarship of the class is actually normally distributed. In the above investigation, as the number of examinations increased there was a closer approach toward the normal type of distribution and when nine tests had been given the actual distribution was practically identical with that of the normal type. This was also true for the elementary classes in chemistry. In general it is the writer's experience that as the methods of examination are refined and as the number of students and the number of tests is increased there is a closer and closer approach toward the normal curve. Mathematically speaking, the normal curve seems to be the limit which, with refinement of method and the elimination of accidental variations, tests of general intelligence approach. It is to be remembered that these students were university freshmen and sophomores upon whom the effects of high school selection have been operative. It is possible that if all the high-school classmates of these students had continued and taken the same course in the university the average accomplishment of the whole class might have been somewhat less, yet it is not likely that the *distribution* would have been different.

That some mental tests are not normally distributed need be no cause for criticism when we recall that the essential factor in grading is *uniformity*. What a particular grade will eventually signify will depend upon how successfully or unsuccessfully the students who are characterized by this grade meet the demands of higher institutions or the demands of the world at large. It will not depend upon whether the grade is found below or above some hypothetical accomplishment of the population at large.

There is another question which might be asked, namely: How many of the ten grades awarded by Reed College represent distinguishable degrees of scholarship? At the University of Missouri only five different grades are awarded, and from working with the records of these students the writer is inclined to believe that students who are only a little above or below the average in some courses tend to approach closer to the average when the grades in their other courses are taken into account. If this is a fact then it is possible that the Reed College grades 5, 6, 7, do not represent different degrees of scholarship. There is no way of determining this at the University of Missouri, but Reed College has the data for making this investigation. If three series were to be formed as follows:

Series I.—Students whose grades are between and including the limits 4–6. (Those students who have no grade higher than 4 nor a grade lower than 6.)

Series II.—The same for the grade limits 5–7.

Series III.—The same for the grade limits 6–8.

If after credit units are considered the averages of these three series are not respectively 5, 6, 7, but approach more closely to each other, say 5½, 6.0, 6½, this would show that the grades 5, 6, 7, do not represent distinguishable degrees of scholarship. It would, no doubt, be of considerable interest to school administrators to have a report from Reed College on this point.

In conclusion we may summarize the arguments in this paper as follows:

Such mental tests as are significant for determining school grades approach the form of the distribution of the normal curve. The deviations from the normal curve may be considerable, but some of the deviation is due to factors other than those of scholarship. Where the deviation is due to a number of interrelated causes it is difficult to assign a value to the effect of a single one of them. In the interest of uniformity in grading it is essential that the *form* according to which the grades are distributed be *the same for the different schools.* Since the normal curve is a purely theoretical invention closely approximating the actual conditions and is at the same time not hampered by empirical considerations, its mathematical simplicity and

the relatively extensive knowledge which we have of its properties, seem to commend it as the most useful curve to represent the type of distribution to which scholarship marks should conform. If it is desirable to have the grades express significant local factors, this can always be done by adding some constant value to these grades, and the constants so found will also give an index as to the scholarship of a particular institution.

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SCIENTIFIC BOOKS

Nature's Harmonic Unity. By SAMUEL COLMAN, N.A. Edited by C. ARTHUR COAN, LL.B. New York, G. P. Putnam's Sons. 1912. Cloth, $8 \times 9\frac{1}{2}$ in. Pp. viii + 327; 302 illustrations. $3.50 net.

The purpose of this book appeals to the scientist and ought to be a matter of serious study for every beginner in the vocation of arts.

It contends to prove that pleasing forms of nature, as well as of human creation, are ruled by mathematical laws.

That this is true to a certain extent has been shown by the reviewer in an article on "Mathematical Principles of Esthetic Forms," which in October, 1900, appeared in the *Monist,* and in various other publications, where also a number of important references may be found. The fact that the author does not seem to be familiar with these accounts for some serious defects in the presentation of the subject. A writer who attempts to explain the principles of esthetic forms in nature should not neglect to study, for example, Schwender's "Vorlesungen über Mechanische Probleme der Botanik."[2] Furthermore, what a rich source of beautiful natural forms might he find in Haeckel's "Kunstformen der Natur."[3]

In neglecting the physiological and psychological factors of the problem, the treatment must necessarily become antiquated and, from the standpoint of the exact scientist, in many parts shrouded by a semi-mathematical mythology and naïvely stated principles.

The book contains, nevertheless, a number of very readable chapters which will be of value to any one interested in the problem. The examples chosen from biology are by far the most interesting, while some of those in architecture are of questionable value. See, for instance, on page 79, the combined figure of a snow crystal and the Parthenon. It is evident that a hexagonal figure may always be drawn to fit the tinted square and resembling a snow crystal. But what about the exact dimensions? Again, the paraphrase of a vase, p. 273, designed according to, what in this and similar cases I call mathematical mythology, is certainly no object of universal admiration. Notice the painfully weak points in the foot.

The Greeks did not know the logarithmic spiral as would appear from a statement in connection with the discussion of the Ionic volute in the chapter on conchology. This particular spiral, expressed by the polar equation $\rho = e^{a\theta}$, was discovered by Descartes in 1638. When writing about the Ionic order, why not mention the Lituus ($\rho^2 = a^2/\theta$) discovered by Cotes in 1722. It seems strange too, that the catenary should be given the prize as the most beautiful curve. Those algebraic lines which pass through the circular points are generally considered as the beauties among the curves.

The technical aspect of the book is generally pleasing. It is, however, to be regretted that in a treatise with esthetic purposes most of the geometric figures should be so crudely drawn. They are clumsy-looking and lack neatness and precision of execution.

[1] "Mathematik in Natur und Kunst," *Mitteilungen der Naturforschenden Gesellschaft in Solothurn,* Vol. XV., 1906. "Sur quelques exemples mathématiques dans les sciences naturelles," *L'Enseignement Mathématique,* Vol. XII., Paris, 1910. "Wiskunde en Natuurlijke Historie," *Wiskundig Tijdschrift,* Vol. 10, Haarlem, 1910. "Mathematics and Engineering in Nature," *Popular Science Monthly,* November, 1911.

[2] Engelmann, Leipzig, 1909.

[3] Leipzig, 1899–1903.